PATENT

Docket No. 979-045

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s)	:	TBA
Serial No.	:	10/729,351
Filed	:	December 3, 2003
For	:	FLEXIBLE ELECTRICAL ELONGATED DEVICE...

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Date: 3/5/04

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Docket No.: 979-045

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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In re Application of :

TBA :

Serial No.: 10/729,351 :

Filed: December 3, 2003 :

For: FLEXIBLE ELECTRICAL ELONGATED DEVICE SUITABLE FOR SERVICE IN A HIGH MECHANICAL LOAD ENVIRONMENT :

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By______________________

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Dated: March 5, 2004

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Bekreftelse på patentsøknad nr
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It is hereby certified that the annexed document is a true copy of the above-mentioned application, as originally filed on 2003.10.21

Priority is claimed from patent application no 20033583 filed on 2003.08.13

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FLEXIBLE ELECTRICAL ELONGATED DEVICE SUITABLE FOR HIGH LOAD ENVIRONMENT

The present invention relates to flexible elongated electrical device suitable for high load environment.

BACKGROUND OF THE INVENTION

The demand for electrical power supply at the sea floor increases with the increasing water depth at which oil production is being performed. This means that electrical energy must be supplied through cables to the subsea system as power or control elements. Two kinds of cables are required: those with large conductor elements, i.e. power cables, and those with small signal conductor elements included in a control system, i.e. signal cables, such as can be found inside umbilical cables). These power cables and umbilicals have to hang freely suspended from the floating production vessel and down to the seabed, i.e. so-called dynamic cables.

Copper is the most common metal used in an electrical conductor element. Although having excellent electrical properties such as high conductivity, copper does not have mechanical properties suitable for withstanding the loads imposed during cable installation and during dynamic service, facing the motions induced by wind, currents and waves, and also the high external pressure at the seabed.

Copper has a high density and a low mechanical strength. The high density indirectly leads to large inertia forces during installation and dynamic service.

The low mechanical strength implies that copper will not contribute much to the cable's overall strength or axial stiffness. Furthermore, copper also has a relatively small acceptable maximum strain limit as well as strain range to operate within during dynamic service as compared to steel.

In the existing power cable technology, conductor elements are wound around each other in a bundle surrounded by a number of load bearing armor layers. The load transferring mechanism from the copper

conductors to the load bearing armor layers is internal friction, which is an unreliable servant.

When the conductor elements are subjected to relatively high tensions, contact forces between the individual copper strands will also be relatively high. Such high contact forces and relative movement between copper strands may cause fretting to occur. And copper has relatively low fretting resistance.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the invention to provide a flexible electrical elongated device suitable for service in a high mechanical load environment by way of example, hanging freely from the sea surface and down to the seabed, in ultra deep water oil field.

The invention thus aims at increasing the reliability of the load-transferring feature from any electrical conductor element to the load-bearing element and to ensure low contact forces and strains in each conductor element.

The invention is particularly appropriate to conductors made of materials of high conductance and low mechanical properties such as copper, but not specially limited to them.

To this purpose, the invention provides a flexible electrical elongated device suitable for service in high mechanical load environments, wherein said device has a longitudinal axis and comprises,:

- At least one elongated electrical conductor element,
- an elongated load bearing component along said longitudinal axis,
- a polymeric layer bonded to the elongated load bearing component,
- and groove(s) disposed on the external surface of said polymeric layer and along said longitudinal axis,

and wherein said groove is designed for holding said electrical conductor element within it while allowing said conductor element to move substantially radially when said device is bent.

As a central element instead of helically wound armor layers, the load bearing component of the invention increases the relative axial stiffness of the element, which thereby ensures lower conductor element strains.

Any kind of component with a suitable strength to weight ratio for the intended service may be chosen for the central element.

The groove in the polymeric layer bonded to the load bearing component holds the conductor in a way to transfer the mass- and inertia forces of the conductor to the load bearing component.

The electrical element can move radially in the groove i.e. towards and away from the load bearing component, to accommodate the bending.

The groove can be straight i.e. in parallel with the longitudinal axis, but preferably, the groove can have a helical shape to reduce the amplitude of the useful radial movement of said conductor element.

In particular, the helical angle of a helical groove can be comprised between 5 and 85 degrees from said longitudinal axis.

The value of the helical angle is determined by the balance between the amount of bending the device will be subjected to, e.g. during installation or dynamic service, and the practical amount of radial sliding the overall element design can accommodate. The helical angle reduces the amount of friction which is relied upon to transfer the mass and inertia forces to the load bearing component.

The helical angle of the groove(s) should be as large as practicably possible and also depends on the available space e.g. the number of grooves or the conductor type.

Whereas the device may also comprise a plurality of parallel grooves, each groove should include only one conductor element.

According to an additional characteristic of the invention, the groove should be tight enough to hold said conductor element substantially continuously along said longitudinal axis, thereby ensuring optimized continuous transfer of mass- and inertia forces in all the length.

In one embodiment, when said device is straight, the cross-section shape of said groove, in a perpendicular plane to said longitudinal axis, is

elliptic and with an average width lower or equal to the radial dimension of said elongated electrical element so that said electrical element fits with elasticity wherein said groove. The shape of the groove allows the necessary radial displacement of the conductor as the said electrical elongated element is bent.

In another embodiment, the cross-section shape of said groove, in a perpendicular plane to said longitudinal axis, is defined by two sidewalls substantially parallel to each other, on which said conductor element is able to slide, and a round like shape bottom wall. A soft filler material is inserted between the conductor element and said bottom wall. The elasticity of the soft filler material allows the necessary radial displacement of the conductor by way of deformation as the said electrical elongated element is bent.

In a third embodiment, the polymeric layer bonded to the load bearing component can be so elastic that the conductor can be snug fit in the groove, and the necessary radial displacement of the conductor is provided by deformation of the elastic layer.

In all embodiments of the invention, the internal core is a rod or a tube or any other device suitable to carry high axial loads and suitable to bond to the polymeric layer. The polymeric layer as well as the polymeric layer/load-bearing element interface is capable of transferring the mass and inertia loads. When the load bearing component is a tube, the flexible electrical elongated device has the capability to transport hydraulic power, lubrication, or chemical injection fluids.

The thickness of the polymeric layer is determined by the size of the electrical elements. Of course, the diameter of the conductor element is lower than the thickness of the elastic layer.

The load bearing component can also be made of a material selected among steel, fiber and composite. The extruded elastic layer bonded to the load bearing component can be made of plastics selected from cross-linked polyethylene and thermoplastic polymer and including said groove.

In one preferred embodiment, the device being a power cable, said conductor element comprises one of the following elements: a high voltage conductor, a medium voltage conductor, a low voltage conductor (small signal conductor) or copper wires stranded together.

According to an additional characteristic of the invention, said device being a vertical power submarine cable, it can comprise an outer protective jacket surrounded said elongated load bearing component. And said groove is filled with seawater.

Said jacket is a barrier against foreign objects, and the sea water filled in the groove(s) provides pressure compensation at large water depths.

According to a second embodiment of the invention the principles may also be applied to one or more of the signal cable elements included in a control system of an umbilical cable hanging freely suspended from a floating production vessel and down to the seabed.

BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics and advantages of the invention will become clear on reading the following description of embodiments of the invention, given by way of examples only, and made with reference to the accompanying drawings in which:

- Figure 1 shows a floating production facility and a flexible riser cable,
- Figure 2 shows a schematic of a prior art power cable cross-section
- Figure 3 is a schematic cross sectional view of a flexible vertical submarine power cable in a straight condition in a first embodiment of the invention;
- Figure 4 is a schematic cross sectional view of the flexible vertical submarine power cable shown in Figure 3 in a straight and bent condition, where the radial displacement of the electrical conductors is indicated;
- Figure 5 indicates three ways of achieving a design that can accommodate the radial displacement, and;

- Figure 6 is a diagrammatic cross sectional view of an umbilical cross-section which incorporates a prior art signal cable element (a) and another umbilical cross-section (b) which incorporates a signal cable utilizing the invention's principles in a second embodiment of the invention;

DETAILED DESCRIPTION

Figure 1 shows a floating production facility 10 floating at the sea surface 20 in ultra deep water. A flexible riser cable 30 (e.g. a dynamic power cable or dynamic umbilical) is hanging towards the seabed 40 in a lazy wave configuration. A lazy wave configuration implies that buoyancy 50 is introduced primarily to dampen out system dynamics. At the platform end, the cable is connected to a power supply, and at the sea bed, the power cable is connected to the appropriate subsea equipment, whether it is a subsea pump 60, a pipeline (for pipeline resistive heating) or any other subsea based, power consuming equipment.

Figure 2 is a schematic cross-section drawing of a prior art dynamic power cable 1. Three insulated power conductors 2 are indicated within outer layers including armouring 3. Details 4 are as follows: These power conductors 2 are preferably large copper conductor made of stranded copper wires encompassed by a plurality of sheaths (not represented in details) including by way of example a conductor screen in semiconducting crosslinked polyethylene (XLPE), surrounded by an insulation sheath of a conductor element XLPE and by an additional sheath of semiconducting polyethylene, and an outer protective jacket surrounding the whole, preferably in polyethylene.

Figure 3a is a schematic cross sectional view of a vertical power submarine cable (not to scale) 11 in a straight position, in a first embodiment of the invention.

Such a cable 11 is a riser cable for delivering power to a subsea system and is hanging freely suspended from a floating production vessel and down to the seabed. By way of example, such a riser cable 11 can replace the classical riser cable 1 shown in Figure 2.

Starting from the center and moving radially, around a longitudinal axis X, the power cable 11 comprises :

- an elongated load bearing component 12 (Fig 3b) including:
  - an internal core 13 preferably a rod or a tube or any other device suitable to carry high axial loads made of a high axial stiffness material such as steel or a composite,
  - and an elastic layer 14 made of a plastic material preferably of crosslinked polyethylene and bonded around the rod 13 and, such a layer 14, preferably extruded, including three helical grooves 15a-c on its external surface,
  - three conductor elements 2 intended to transport electrical energy, placed within one distinct groove 15a-c respectively.

The helical grooves 15a-c extend all along the power cable 11 and preferably are equally spaced from each other.

The helical angle of each groove 15a-c is comprised between 5 to 85 degrees from the longitudinal axis, - depending on the available space.

The cross-section shape of the grooves 15a-c is elliptic like, without taking into consideration the opening O. The maximum width L of the ellipse is slightly lower or equal to the diameter of the conductor elements 2 so that they tend to stay in a centralized position in the groove when the power cable 1 is in the straight condition.

In this groove design, these conductor elements 2, are held continuously in their whole length and additionally are disposed on purpose in a middle position from the bottom walls BW of the grooves and the openings O, forced to this position during their installation.

One or more outer covers 16 allowing penetration of sea water may be provided and, - moreover, each groove 15a-c is preferably allowed to be flooded with seawater to provide pressure compensation at large water depths.

Furthermore, each groove 15a-c allows the conductor elements 2 inside to move substantially radially when the power cable is bending.

At a fixed interval along the groove, the groove is made wider than the conductor element to allow water to move as the conductor moves (not shown).

Figures 4a-b illustrate how the conductor elements 2a-c move when the cable is bent.

The cable 11 shown in Figure 4 is bent towards a given direction. The upper cable element 2a slides radially towards the axis X of the power cable 11 while the second and third cable elements 2b-c slide radially away from the axis X.

When the bending is reversed, and the cable is brought back to the straight condition, the cable elements 2 slide in the opposite direction therefore returning to the middle way position.

Figure 5 is a diagrammatic cross-sectional view of three ways the grooves can be made to accommodate the radial displacement the conductor elements experiences as the power cable is bent.

Figure 5a shows the principle described above under the explanation to Figure 4a.

In Figure 5b the cross-section shape of the groove 15 is defined by two parallel sidewalls SW and a round like shape bottom wall BW.

A soft filler material 21 is inserted between the conductor element 2 and the bottom wall BW. Each groove 15 is also preferably filled with seawater.

The distance L between the side walls SW is lower or equal to the diameter of the conductor element 2 inside to hold them in a centralized position of the power cable 11.

In this groove design, the conductor elements 2 are held continuously in the whole length and additionally are disposed on purpose in a middle way position from the bottom walls BW of the grooves and the openings O of the grooves 15.

Furthermore, each groove 15 and soft filler 21 allow the conductor element 2 inside to move substantially radially when the power cable is bent.

When the bending is reversed and the cable element brought back to a straight condition, the cable elements 2 slide in the opposite direction returning to the middle way position.

In Figure 5c, the polymeric layer 22 - corresponding to layer 14 bonded to the rod 13 of Figure 3b - is made of a sufficiently soft material so that deformation of the polymeric layer accommodates the conductor's radial displacement.

Figure 6 shows the invention in a second embodiment of the invention. Figure 6a shows a conventional dynamic umbilical cross-section 31 including one prior art signal cable element 32 (Figure 6c).

Figure 6b shows a similar dynamic umbilical 41 with the invention's principles applied to the signal cable element 32, - now designated 42 (Figure 6d). Such a cable 42 is one of many internal elements of an umbilical cable of a control system, and is hanging freely suspended from a floating production vessel and down to the seabed similar to what is illustrated in Figure 1. The plastic center element 33 (Figure 6a) in the umbilical 31 has in umbilical 41 (Figure 6b) been exchanged with a tube 43 corresponding to the tube 34 (Figure 6a) in order to maintain a number of six tubes if so required by a customer.

Starting from the center of the signal element and moving radially, the multifunctional element 42 comprises:

- an internal core 44 preferably a rod or any other device suitable to carry high axial loads and made of a high axial stiffness material such as steel. The core 44 could preferably be a tube (not shown) preferably containing hydraulic fluid delivered to a subsea control system,
    - and an elastic layer 45 made of thermoplastic polymer and bonded around the rod/tube 44 and, such a layer 45, preferably extruded, including helical grooves 46 on its external surface,
- conductor elements 47 intended to transport electrical energy - or control signals, placed within the grooves 46

The helical grooves 46 extend all along the multifunctional element 42 and preferably are equally spaced from each other.

The helical angle of the grooves 46 is some 5 to 85 degrees with the longitudinal axis, depending on the available space.

The cross-section shape of the grooves 46 is chosen among the alternatives indicated in Figure 5. Each groove 46 allows the conductor element 47 inside to move substantially radially when the signal cable is bent.

When the bending is reversed and the cable element brought back to a straight condition, the cable elements 47 slide in the opposite direction returning to the middle way position.

CLAIMS

1. Flexible electrical elongated device (11,42), suitable for high load environment, wherein said device has a longitudinal axis (X), and comprises,:
   - at least one elongated electrical conductor element (2,47),
   - an elongated load bearing component (14,45) along said longitudinal axis,
   - and at least one groove (15,46) disposed on the external surface of said load bearing component and along said longitudinal axis,

   and wherein said groove is designed for holding said electrical conductor element within it while allowing said conductor element to move substantially radially when said device is bent.
2. Flexible electrical elongated device (11,42) according to claim 1 wherein said groove (5,46) has an helical shape.
3. Flexible electrical elongated device (11,42) according to claim 2 wherein the helical angle of said helical groove (15,46) is comprised between 5 and 85 degrees from the longitudinal axis.
4. Flexible electrical elongated device (11, 42) according to any of claims 1 to 3 wherein it comprises a plurality of parallel grooves (15,46), each one including only one conductor element (2,47).
5. Flexible electrical elongated device (11,42) according to any of claims 1 to 4 wherein said groove (15,46) is tight enough to hold said conductor element (2,47) substantially continuously along said longitudinal axis (X).
6. Flexible electrical elongated device (11,42) according to any of claims 1 to 5 wherein, when said device is straight, the cross-section shape of said groove (15,46), in a perpendicular plane to said longitudinal axis (X), is elliptic and with an average width (L) lower or equal to the radial dimension of said elongated electrical element (2,47) so that said electrical element fits with elasticity wherein said groove.

7. Flexible electrical elongated device (11.42) according to any of claims 1 to 5 wherein the cross-section shape of said groove (15,46), in a perpendicular plane to said longitudinal axis (X), is defined by two sidewalls (SW, Fig 5) substantially parallel to each other, on which said conductor element (2,47) is able to slide, and a round like shape bottom wall (BW), and wherein a soft filler material (21) is inserted between the conductor element and said bottom wall.

8. Flexible electrical elongated device (11,42) according to any of the claims 1 to 7 wherein the polymeric layer (22, Fig 5c) bonded to the load bearing component (13) can be so elastic that the conductor can be snug fit in the groove, and the necessary radial displacement of the conductor is provided by deformation of the elastic layer.

9. Flexible electrical elongated device (11,42) according to any of claims 1 to 8 wherein said load bearing component (12,44/45) comprises an internal core (13, 44) along said longitudinal axis (X) and made of high axial stiffness material and comprises an elastic layer (14, 45) bonded around said internal core and including said grooves (15,46) on the external surface.

10. Flexible electrical elongated device (11,42) according to any of claims 1 to 9 wherein said load bearing component (12,44/45) comprises an internal core (13, 44) along said longitudinal axis (X) and including a multifunction tube suitable for transporting hydraulic power and/or lubrication.

11. Flexible electrical elongated device (11,42) according to any of claims 1 to 10 wherein said load bearing component (12,44/45) comprises an internal core (13, 44) extended along said longitudinal axis (X) and made of a material selected among steel, fiber and composite, and comprises an extruded elastic layer (14,45) made of plastic selected from crosslinked polyethylene and thermoplastic polymer and including said groove (15,46).

12. Flexible electrical elongated device (11,42) according to any of claims 1 to 11 wherein said device being a power cable, said conductor element (2) comprises one of the following elements: a high voltage conductor, a medium voltage conductor; a low voltage conductor or copper wires stranded together.

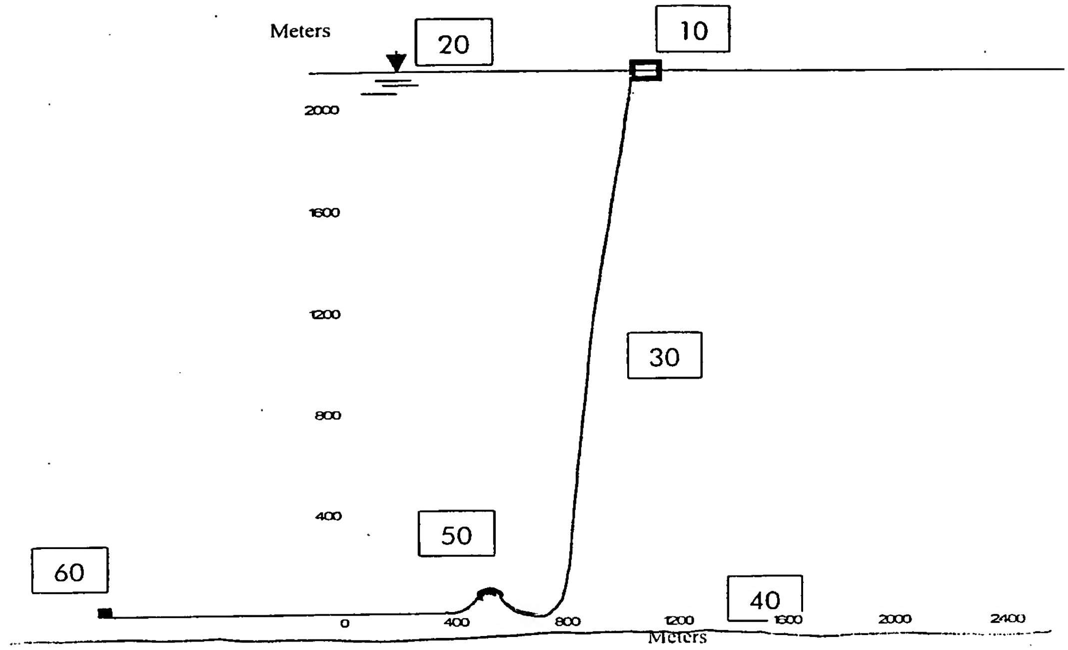
13. Flexible electrical elongated device (11,42) according to any of claims 1 to 12 wherein, said device being a vertical power submarine cable (11) or a signal/power element (42), it comprises an outer protective jacket (16) surrounding said device and wherein said grooves (15,46) is filled with seawater.

ABSTRACT

The demand for electrical power supply at the sea floor increases with the increasing water depth at which oil production is being performed. This invention relates to a flexible electrical elongated device suitable for high load environment, wherein said device has a longitudinal axis, and comprises:

- at least one elongated electrical conductor element,
- an elongated load bearing component along said longitudinal axis,
- and at least one groove disposed on the external surface of said load bearing component and along said longitudinal axis,

and wherein said groove is designed for holding said electrical conductor element within it while allowing said conductor element to move substantially radially when said device is bent.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Meters

Fig. 1

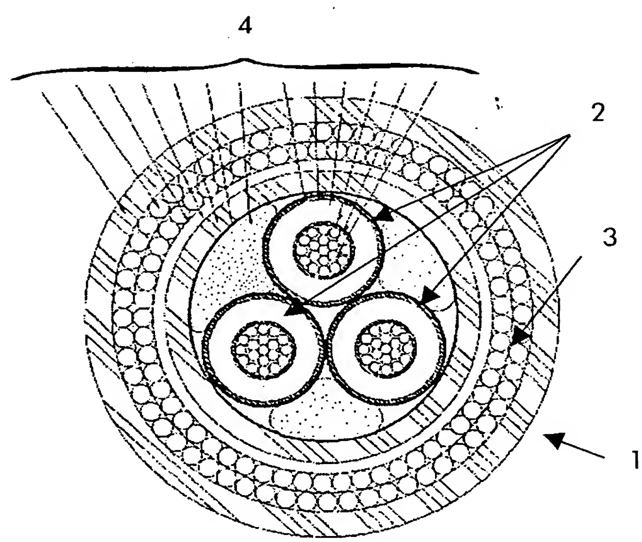

4
2
3
1

Fig. 2

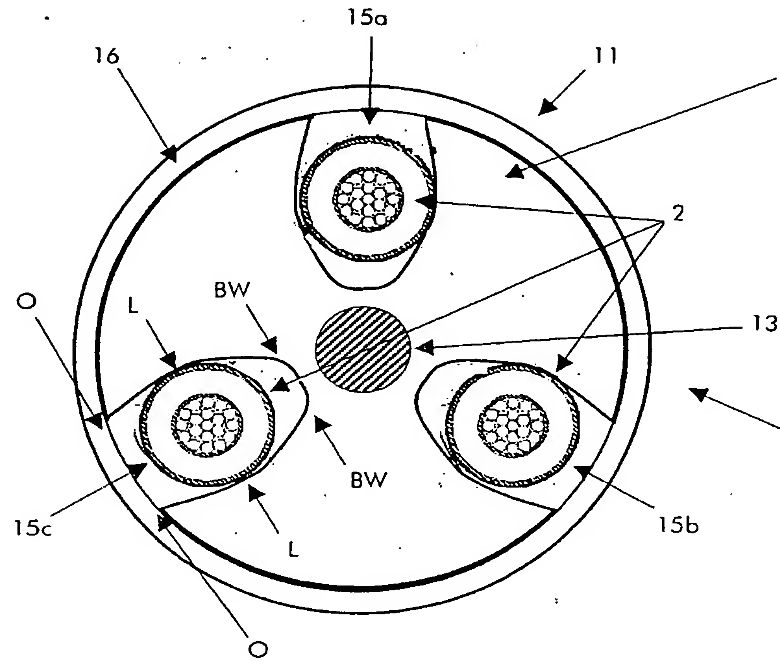


Fig. 3 a)

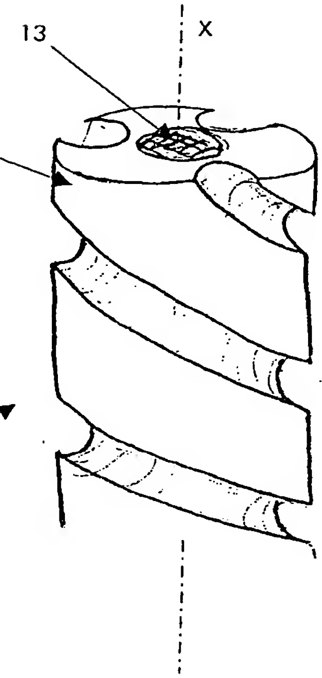


Fig. 3 b)

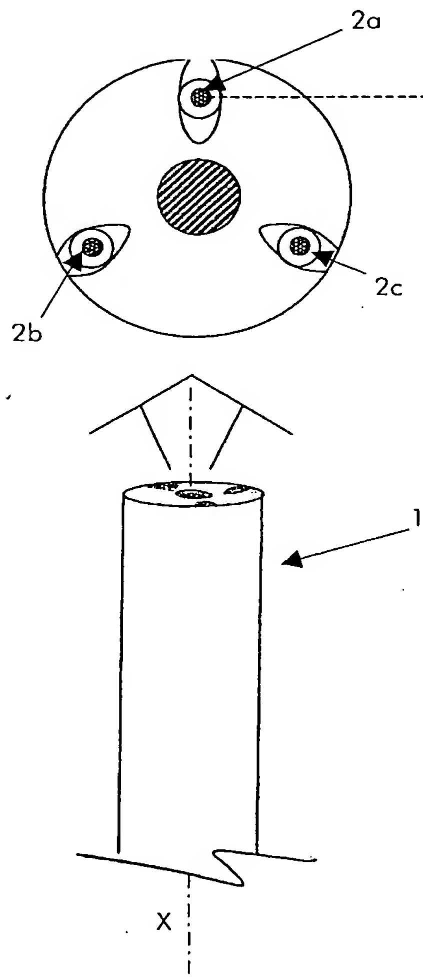


Fig. 4 a)

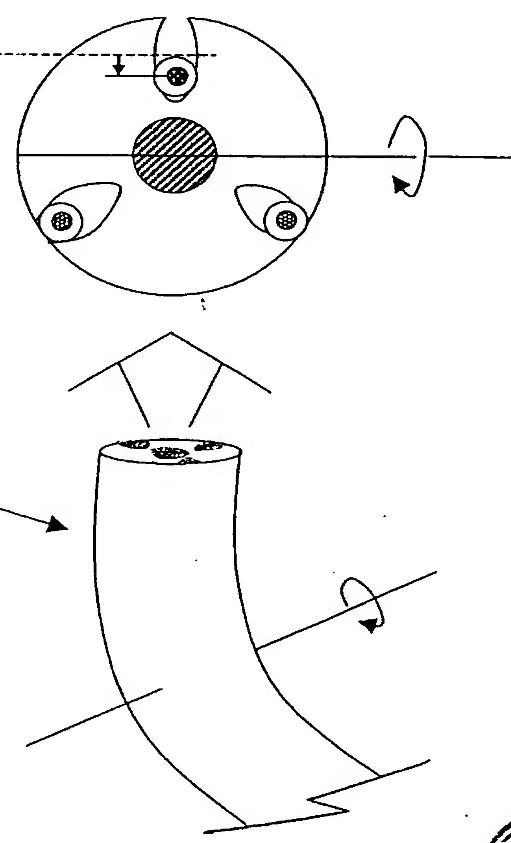
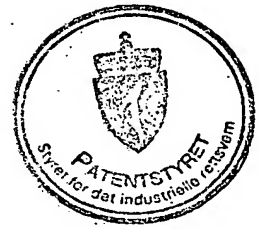


Fig. 4 b)



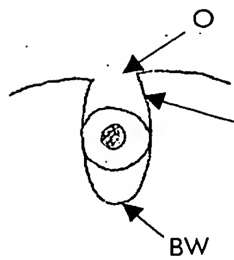


Fig. 5 a)

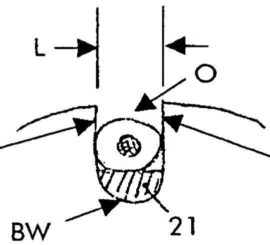


Fig. 5 b)

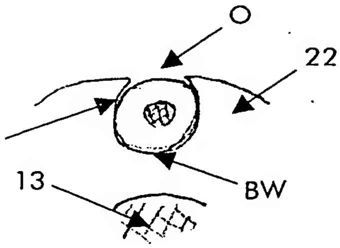


Fig. 5 c)

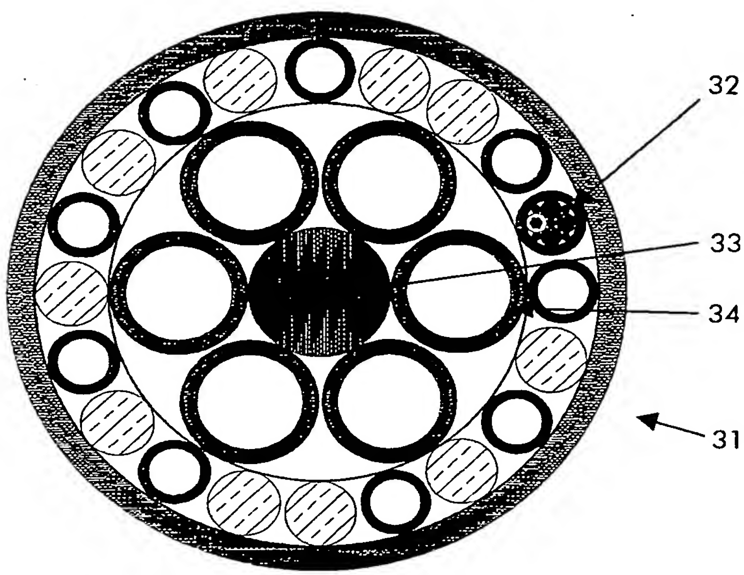


Fig. 6 a)

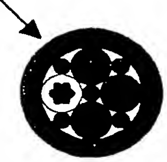
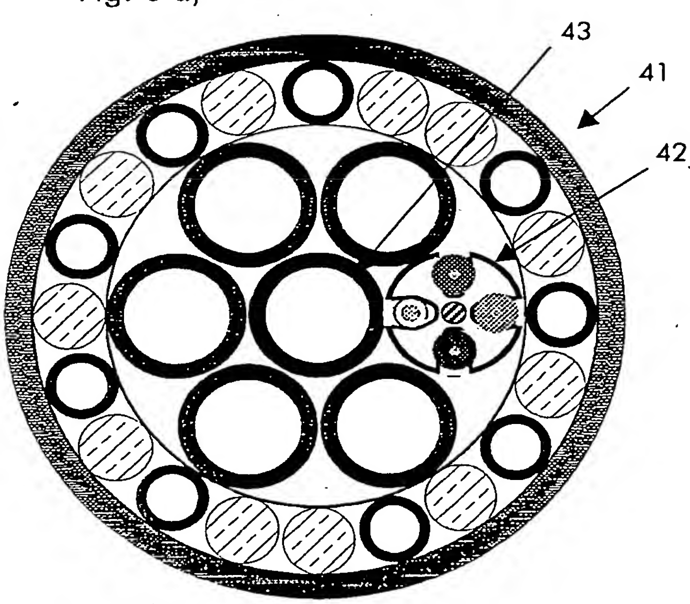


Fig. 6 c)



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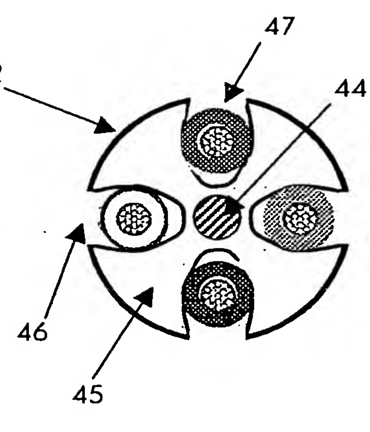

Fig. 6 d)